**UNIVERSITI PUTRA MALAYSIA**

# THE CONTRIBUTION OF CROP RESIDUES IN SUSTAINABLE PRODUCTION OF MAIZE AND GROUNDNUT IN A CROP ROTATION SYSTEM

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# THE CONTRIBUTION OF CROP RESIDUES IN SUSTAINABLE PRODUCTION OF MAIZE AND GROUNDNUT IN A CROP ROTATION SYSTEM

**By**

**MUBARAK ABDELRAHMAN ABDALLA**

**Thesis Submitted in the Fulfilment of the Requirement for the Degree of Doctor of Philosophy in the Faculty of Agriculture Universiti Putra Malaysia**

**April 2001**

## DEDICATION

To my late father, my mother, my wife staff nurse: Niemat Ibrahim, my daughters (Rawan and Gufran), my son (Ahmed), brothers, sisters and all relatives.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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**Chairman:** **Associate Professor Rosenani Abu Bakar, Ph.D.**

**Faculty:** **Agriculture**

Field and laboratory experiments were carried out with the main objective of studying the contribution of crop residues in sustaining yields of maize (*Zea mays* L.) and groundnut (*Arachis hypogaea*) in a crop rotation system under Malaysian tropical conditions. Five cropping seasons of a rotation of sweet corn – groundnut - sweet corn – groundnut - sweet corn was conducted with three treatments (i) recommended inorganic fertilizer with crop residues (T1), (ii) recommended inorganic fertilizer without crop residues (T2) and (iii) combination of inorganic fertilizer and chicken manure (10 t ha $^{-1}$) with crop residues (T3). The $^{15}N$ tracing technique was used to study the fate of applied inorganic fertilizer, $(^{15}NH_4)_2SO_4$ , in T1 and T2 treatments. All the plots were limed at 2 t ha$^{-1}$ before sowing each crop. Two secondary experiments were carried out in the main field experiment to (i) investigate nutrient release from decomposing $^{15}N$-labelled maize stover and N uptake by the subsequent groundnut crop using mineralization tubes and (ii) to compare the decomposition rates and nutrient release patterns of maize and groundnut residues using litterbags. Also, two incubation studies were conducted in

the laboratory, first, to determine potential N mineralization rates from above and below ground crop residues and second to determine potential N - mineralization rates of maize stover and groundnut haulm in selected five Malaysian soil series.

Results showed that continuous incorporation of crop residues (2.4 – 4.4 t dry matter (DM) ha $^{-1}$ of maize stover and 2.7-5.6 t dry matter ha $^{-1}$ of groundnut haulm) with inorganic fertilizers or combined with chicken manure was found to sustain 43% of the observed maximum yield (calculated according to Singh et al., 1990) of the maize yield compared to 21% in plots where crop residues were removed. Nitrogen and K uptake by the subsequent crops were significantly ($P \leq 0.05$) higher in crop residue treatments whereas P, Ca and Mg were not significantly affected by application of crop residues. Soil pH, organic carbon, cation exchange capacity, soil resistance, soil water content and soil bulk density were not significantly changed with recycling of crop residues probably because of rapid turnover of the organic matter. The light fractions or particulate soil organic matter appeared to be higher, but not significant, after four applications of crop residues. Soil available P and exchangeable K were significantly ($P \leq 0.05$) higher in crop residue treated plots. Recoveries of applied fertilizer $^{15}N$ by the first crop ranged from 19.3 to 21.6%. In the 2$^{nd}$ crop, the recoveries were 5.1% in T1 and 5.6% in T2 and only traces of fertilizer $^{15}N$ recovered in the following crops. In the soil (0-50 cm), the retention of fertilizer N in the soil after harvest of the first crop was 35.3 to 43.8% whereas after harvest of the subsequent crops, this proportion averaged 28.8% (24.9 - 33.5%) in T1 with residues and 23.8% (18.1 - 30.1%) in T2 plots without residues. Recovery of maize residue-$^{15}N$ in the subsequent crops averaged only 3.3% (0.47 - 10.71%). The recovery of maize residue $^{15}N$ in the soil (0-50 cm) was 56.2% (39.9 - 85.0%)

averaged across seasons. Nitrogen mineralization from maize residues was very rapid with its peak occurring between 4 to 8 weeks after incorporation of the residue. Consequently, for optimum N synchrony, sowing of the subsequent crop in the rotation is recommended to be 4 to 6 weeks after incorporation of the residue. Groundnut haulm decomposed at a rate of 0.158% week $^{-1}$ compared to 0.099% week $^{-1}$ for maize stover. One week after application of the maize and groundnut residues, 20 and 43 kg N $ha^{-1}$, respectively were made available to the subsequent crop. Net N-mineralization (12.7 - 23.8 $\mu g$ N $g^{-1}$) from crop residues was only observed in the Bungor series whereas in other soil series soil mineral N completely disappeared during the incubation period indicating net immobilization. Soil texture was observed to have no clear effect on N-mineralization from crop residues. This study showed that decomposition of crop residues seemed to be rapid in the environmental conditions of Malaysia. Therefore, management of crop residues during the fallow periods is essential for improving the fertility of these soils for better sustainable crop production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi keperluan penganugerahan ijazah Doktor Falsafah

**SUMBANGAN SISA TANAMAN TERHADAP PENGELUARAN JAGUNG DAN KACANG TANAH YANG LESTARI PADA SEBUAH SISTEM PENGGILIRAN TANAMAN**

**Oleh**

**MUBARAK ABLDELRAHMAN ABDALLA**

**April 2001**

**Pengerusi: Profesor Madya Rosenani Abu Bakar, Ph.D**

**Fakulti : Pertanian**

Kajian di lapangan dan makmal telah dijalankan dengan objektif utama untuk mengkaji keberkesanan kitaran semula sisa tanaman terhadap pengeluaran jagung dan kacang tanah yang lestari melalui kaedah penggiliran tanaman. Lima musim tanaman (kajian utama) iaitu penggiliran tanaman jagung manis - kacang tanah - jagung manis - kacang tanah - jagung manis telah dijalankan dengan menggunakan tiga jenis rawatan. Rawatan pertama (T1) ialah penggunaan baja kimia dan sisa tanaman, rawatan kedua (T2) ialah penggunaan baja kimia sahaja tanpa sisa tanaman dan rawatan ketiga (T3) ialah penggunaan baja kimia bersama tahi ayam 10 tan $ha^{-1}$ dan sisa tanaman. Teknik pengesanan $^{15}N$ telah digunakan untuk menentukan pergerakan dan nasib baja kimia ($(NH_4)_2 SO_4$) dalam rawatan T1 dan T2. Semua plot kajian diberikan rawatan pengapuran sebanyak 2 t $ha^{-1}$ sebelum penanaman setiap tanaman. Dua kajian sekunder dijalankan pada plot utama untuk (i) mengawasi pelepasan nutrien daripada pereputan sisa jagung yang telah dilabelkan dengan $^{15}N$ dan pengambilan N oleh tanaman berikutnya (kacang tanah), dan (ii) membandingkan kadar pereputan dan corak pelepasan nutrien daripada sisa jagung

dan kacang tanah. Dua kajian pengeraman juga dijalankan; pertama untuk menentukan potensi kadar mineralisasi N daripada sisa tanaman bahagian atas dan bawah tanah; kedua, mengkaji pengaruh jenis 5 siri tanah Malaysia terhadap potensi mineralisasi N sisa jagung dan kacang tanah.

Keputusan daripada kajian utama menunjukkan bahawa rawatan sisa tanaman yang berterusan (2.4 - 4.4 t $ha^{-1}$ berat kering sisa jagung dan 2.7 - 5.61 t $ha^{-1}$ berat kering sisa kacang tanah) bersama pemberian baja kimia (T1) atau campuran dengan tahi ayam (T3), memberikan hasil jagung yang berkekalan pada tahap 43% (daripada hasil maksimum yang diperolehi), berbanding 21% pada plot tanpa sisa tanaman. Pengambilan N dan K oleh tanaman berikutnya pada dalam plot yang diberikan rawatan sisa tanaman adalah dengan ketaranya lebih tinggi (signifikansi pada $P<0.05$) daripada plot yang tidak dirawat dengan sisa tanaman, dan pengambilan P, Ca dan Mg pula tidak berbeza dengan ketara (secara statistik) diantara ketiga-tiga rawatan. Karbon organik, pH tanah, keupayaan pertukaran kation, kerentangan tanah, kandungan air tanah dan ketumpatan tanah tidak menunjukan perbezaan yang ketara diantara rawatan, kemungkinan disebabkan oleh pereputan bahan organik yang sangat cepat dalam keadaan tropika ini. Walaupun bahagian ringan atau partikulat bahan organik tanah didapati lebih tinggi, dengan rawatan sisa tanaman yang berterusan secara statistik, ia tidak ketara. Fosforus tersedia dan K-tukarganti adalah lebih tinggi dalam plot yang dirawat dengan sisa tanaman. Peratusan $^{15}N$ baja yang diambil oleh tanaman pertama adalah dalam julat 19.3 ke 21.6%. Tanaman kedua memberikan kedapatan semula $^{15}N$ baja sebanyak 5.1% dalam T1 dan 5.6% dalam T2, dan tanaman berikutnya hampir tidak langsung mengambil $^{15}N$ baja yang ditambah. Baja $^{15}N$ yang ditahan dalam tanah (0-50 sm) pula adalah dalam julat

35.3 hingga 43% selepas musim pertama dan selepas penuaian tanaman-tanaman berikutnya, adalah dalam purata 28.8% dalam plot T1 dan 23.8% dalam plot T2. Kedapatan semula $^{15}$N oleh tanaman-tanaman berikutnya berpurata 3.3% (0.47 - 10.71%). Kedapatan semula baja $^{15}$N sisa jagung dalam tanah (0-50sm) berpurata 56.2% (39.9 - 85.0%) dalam kelima-lima musim tanaman. Mineralisasi N daripada sisa jagung adalah sangat cepat dengan kadar yang tinggi sekali dalam tempoh di antara minggu ke 4 dan ke 8 selepas ditambah sisa tanaman. Oleh itu, untuk mengoptimakan pengambilan N daripada sisa tanaman, penanaman berikutnya perlu dilakukan diantara minggu ke 4 hingga minggu ke 6 setelah ditambah sisa tanaman. Sisa tanaman kacang tanah mereput pada kadar 0.158% minggu$^{-1}$ berbanding dengan 0.099% minggu$^{-1}$ pereputan sisa tanaman jagung. Seminggu selepas penambahan sisa tanaman kacang tanah dan jagung, 20 dan 43 kg N ha$^{-1}$ masing-masing menjadi tersedia untuk tanaman berikutnya. Kadar mineralisasi N bersih (12.7 - 23.8 ug N g$^{-1}$) daripada sisa tanaman didapati berlaku hanya pada tanah siri Bungor dan penambahan N mineral tidak dapat dikesan dalam jenis tanah lain. Tekstur tanah didapati tidak memberi kesan yang ketara terhadap pemineralan N daripada sisa tanaman. Kajian ini menunjukkan bahawa pereputan sisa tanaman dalam keadaan persekitaran di Malaysia adalah sangat cepat. Oleh itu pengurusan sisa-sisa tanaman semasa tanah rang adalah penting bagi meningkatkan kesuburan tanah untuk pengeluaran tanaman yang lestari.

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I certify that an Examination Committee met on 6th April 2001 to conduct the final examination of Mubarak Abdelrahman Abdalla on his Doctor of Philosophy thesis entitled "The Contribution of Crop Residues in Sustainable Production of Maize and Groundnut in a Crop Rotation System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination committee are as follows:

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I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

Mubarak

MUBARAK ABDELRAHMAN ABDALLA

Date: 02 MAY 2001

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# CHAPTER I

# INTRODUCTION

## 1.1 Sustainable Crop Production and Soil Organic Matter

Sustainable agriculture has often been used to mean maintaining certain conditions of productivity or environment (Farshad and Zinck, 1993). The most direct measure of sustainability is crop or system productivity. If, with steady input, yield stayed steady relatively for long periods of time, there is an implication of sustainability (Jones, 2000). In this context, declining yields imply non-sustainability, although they may later stabilize at low levels. Soil is an essential natural resource that provides a medium for plant growth, regulates and partitions water flow in the environment, and serves as an environmental buffer in the formation, attenuation, and degradation of natural and xenobiotic compounds (Larson and Pierce, 1991). Management that causes a decline in soil quality reduces these functional abilities. Hence, appropriate management practices for specific crops, soils and agroecological zones aimed at sustaining high crop yields and preventing soil degradation is one of the key factors in the development of a sustainable agricultural system in the humid tropics. This is because agricultural production in the humid tropics has become increasingly sedentary and is essentially "soil-mining" (Lal and Stewart, 1992). The organic contents of soils are vitally important in providing energy, substrates, and the biological diversity necessary to sustain these soil functions. The "soil quality" concept has recognized soil organic matter as an important attribute that has a great deal of control on many of the key soil functions (Doran and Parkin, 1994, Reeves, 1997) and is generally one of the several criteria used to estimate soil quality. It is generally recognized that greater organic matter in the soil layers can improve soil structure (Salih et al., 1998; Salinas-Garcia et al., 1997), increase water infiltration rates (Freese et al., 1993; Jones et al., 1994), alter nutrient availability to plants (Ekwue and Stone, 1995; Fattah and Upadhyaya, 1996; Hulugalle et al., 1997; Somalkar et al., 1991), as well as increase the presence of earthworms and its distribution in the soil profile (Wyss and Glasstetter, 1992).

Plant matter (roots, root exudates and above ground materials) is the major source of organic (carbon based) materials that builds soil organic matter. Soil microbes, animal bodies and their waste also contributes to soil organic matter by directly or indirectly processing plant materials. The addition of plant materials or other organic substances is essential to build or maintain soil organic matter. However, the amounts needed vary according to soil texture, initial organic matter content, management system and climate (especially moisture and temperature).

**1.2 State of the Problem**

Farmers of the world farm 1,478 million hectares of land in order to feed the world. According to Antonio and Rodolfo (1998) that in the next quarter of a century, demand for food will rise dramatically in developing countries for they will be the home of 78.6% of the world population in 2000, this portion will jump to 82.5% by the year 2025. It is crucial that the agricultural sector be the target to feed